Trident Warrior Buoy Testing

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LONG-TERM GOALS

Our long term goals are to improve our ability to characterize and forecast ocean surface waves. Most all at-sea Naval operations depend on knowledge of the conditions of the sea surface in one form or another. This includes the forecasting of EM/RF propagation near the ocean-surface as sea surface roughness has a profound influence on transmission characteristics. The world's oceans are data poor with respect to in-situ wave observations that are suitable for assimilation into, and verification with, operational global wave models (WAM, WaveWatch III). Data that is routinely available to models are satellite-based and have their own set of challenges. For example, remote sensing of the surface wave field using techniques such as radar altimetry or synthetic aperture radar (SAR) provides some measure of bulk wave properties, such as significant wave height or mean wave direction, and can be used to adjust global wave models. However, the techniques suffer from several issues: poor spectral resolution (e.g., differentiating swell vs. seas); the estimation of wave height is dependent on semi-empirical models or modulation transfer functions that have inherent errors: and the satellite repeat time over a particular region of the ocean is too long to reliably improve. Global wave models suffer additional challenges as the wind forcing terms are derived from models (COAMPS, NOGAPS) that have their own set of data sparse challenges, and wave-current interactions are typically neglected due to poor measurements of ocean surface currents.

OBJECTIVES

The Trident Warrior 2013 (TW13) demonstration exercise brought together basic and applied scientists to demonstrate new technologies that can provide remote sensing and real-time oceanographic data during a fleet exercise. For TW13, the U.S. Office of Naval Research sponsored a research effort with two objectives: 1) Assess the influence of the environment on electromagnetic (EM) and radio frequency (RF) propagation for purposes of both radar detection and communications, and 2) Coupling of nowcast/forecast environmental models with unattended sensing platforms including unmanned underwater vehicles (UUVs), unmanned surface vessels (USV), buoys and drifters.

Our contribution to the Trident Warrior 2013 effort was the deployment and operation of a small buoy array that was located in the footprint of the scientific study area. Previously developed GPS miniature

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buoy technology was leveraged. The buoys allow for the sensing and reporting of the ocean surface directional wave spectrum using velocity measurements of X,Y, and Z. The buoys are typically currently configured for drifting operations and only have had moderate success as a moored system due to mooring tension bias. New for this program was the implementation of a compliant mooring and a larger reserve buoyancy package to allow the system to be safely moored, yet still follow the sea-surface. Use of compliant tethers for this application are not new, with commercially available 1m diameter buoys using this approach. However, in contrast to those systems, our proposed solution is a 1-man portable buoy with dimensions similar to a basketball. For Trident Warrior, we tested new mooring technology.

APPROACH

With previous ONR investment in instrumentation development, proof-of-concept of a low-cost, GPS-based wave buoy that is able to reliably transmit data using the Iridium satellite network has been developed and demonstrated. Achievements with that effort include:

- GPS-based wave measurements provide a reasonable means for wave measurements. Validated to Hs ~5m and directional wave spectra are consistent with conventional, moored wave buoys.
- Iridium satellite communications proven robust globally.
- The buoy can be reliably deployed and recovered by untrained personnel.
- Bi-directional communications allows for adaptive sampling intervals during events.

As an advanced prototype, the MOD-0 version of the miniature GPS buoy was highly successful. However, over the course of manufacturing and operating the buoys for the initial two years, shortcomings were identified:

- The existing hardware architecture has limited microprocessor memory and processing capability, which impacts the ability to resolve swell due to the small Fast Fourier Transforms (FFT) size. This shortcoming introduced errors in using the data to track swell events, accurately model swell refraction, and use the data to drive surf-forecasting and other nearshore models (e.g., DELFT 3-D).
- The present manufacturing quality results in significant testing of each system prior to deployment. Unexpected failures still occur in the field.
- The hardware architecture of the system is limited in ability to expand and measure other parameters (e.g., barometric pressure, sea surface temperature, etc.).

In the past year, these shortcomings have been addressed, and many new features have been introduced into the MOD-1 version of the miniature GPS wave buoy, such as:

- Migration of the electronic architecture to an ARM-based micro-controller (similar chip to that used on modern cell phones). The advantages of the new system include efficient FFTs and an ability to use 17 minute FFT windows (1024 samples at 1 Hz) akin to de-facto benchmark wave buoy systems. The longer FFT window allows for higher resolution in the swell bands as

compared to the MOD-0 configuration, which used a 128 second FFT window. The ARM-based chips are also lower power and lower cost, resulting in a unit cost that is approximately half that of the present generation.

- Use of a lower power and smaller Iridium modem.
- Addition of a thermistor to measure Sea Surface Temperature (SST).
- Addition of a 8GB Micro-SD card for on board time series storage (can be unpopulated or disabled).
- A complete rewrite of the software code including implementation of improved signal processing steps such as windowing, averaging, and computation of the first five Fourier coefficients for the wave directional spectrum, which are used for mean direction and directional spread.
- Implementation of a slightly larger, ruggedized hull form that allows for nine months of operation on alkaline batteries (Figure 1).

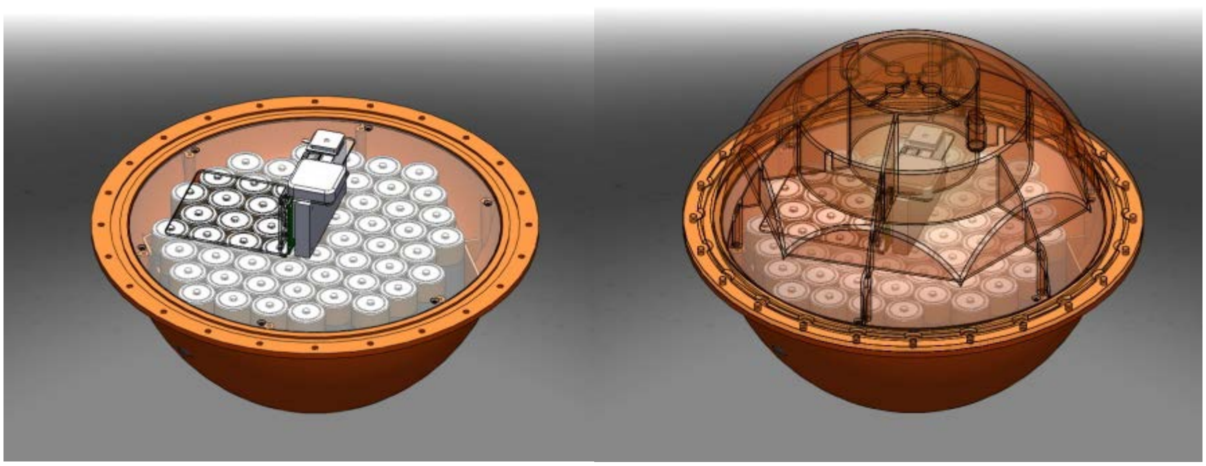

Figure 1. Various hull forms of the miniature GPS wave buoy. Left and middle: The MOD-1 2-week configuration and 3-month configuration buoy. Right: MOD-1one-year buoy hull-form and an explosion diagram of the internal configuration. The battery pack serves as ballast to ensure the buoy remains upright.

WORK COMPLETED

Our efforts for TW13 included the following:

- Coordinate scientific operations with the Trident Warrior Science Team. Work closely with wave modelers from Naval Research Laboratories for final design of the buoy array configuration.
- Build and deploy a five buoy array to be moored on the east coast shelf in waters not to exceed 30m.
- Operate a drifting wave buoy as time allowed in the footprint of measurement array.
- Relay buoy data to NRL for data assimilation in SWAN and other wave models.

- Synthesize buoy data after the experiment for purposes of assessing the ocean model results and to examine shelf propagation of surface waves, and their dampening by the seafloor.

In support of Trident Warrior, CORDC deployed Miniature Wave Buoys - Near Real-time (MWB-NRT) S/N 272, 273, 274, 275, 276, 277 in moored mode on July 8 – 19, 2013. The buoys' positions are shown in Figure 2, or can also be accessed at http://cordc.ucsd.edu/projects/wavebuoys/login.php

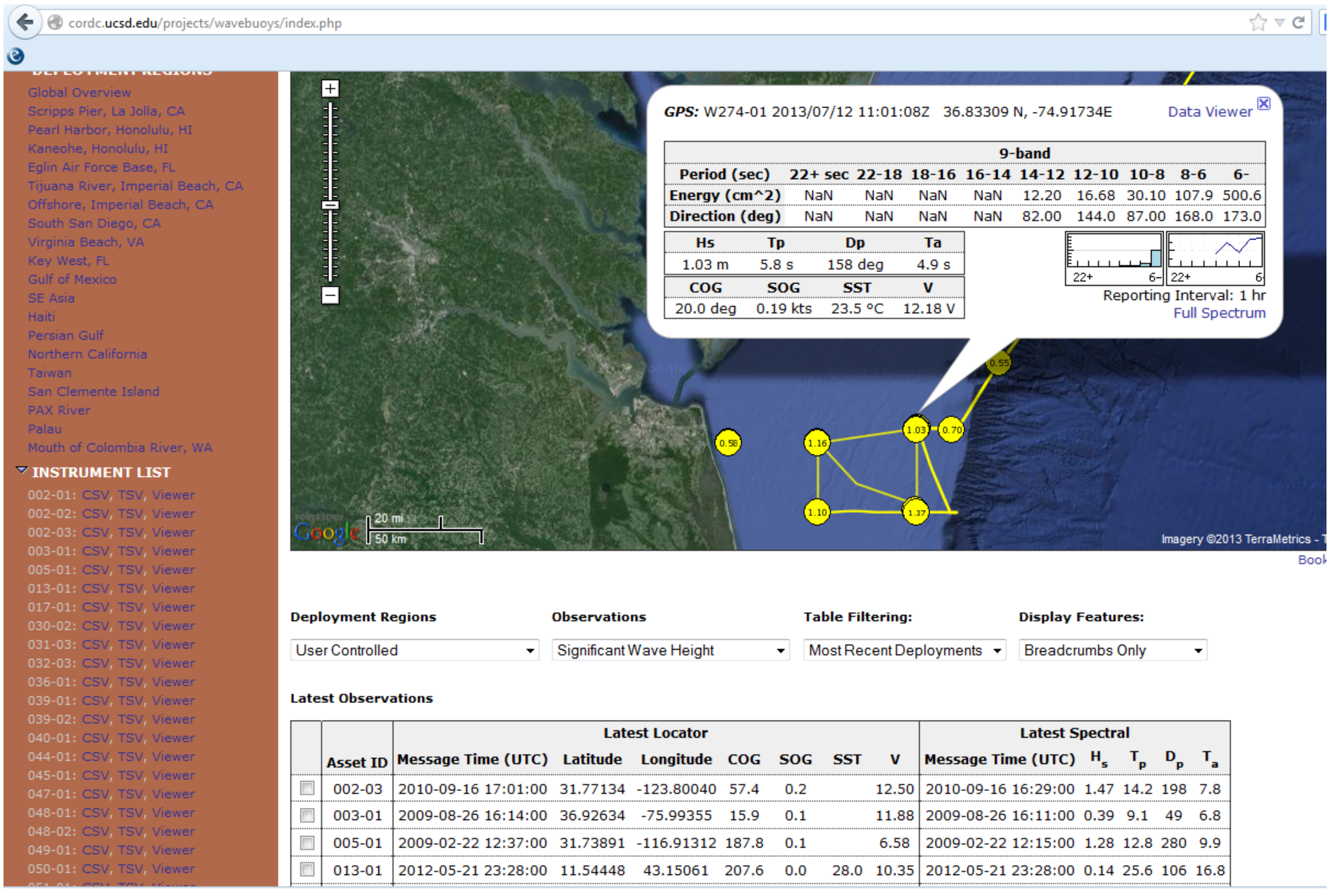

Figure 2 – Snapshot (as of 8/15/13) of Miniature Wave Buoys – Near-realtime (MWB-NRT) deployed in support of the Trident Warrior.

RESULTS

Data from the buoy array is now being evaluated as the systems were recovered recently at the close of the field program. Data throughput was superior during the exercise, with very few dropped messages. A low-frequency bias was visible in some of the moored systems, but has been deemed to be at a frequencies lower than the seawaves and can be removed from the data set. No results are ready yet for distribution.

IMPACT/APPLICATIONS

None to report.